**Chapter 8. Manipulator-Mechanism Design**

**12-1-14**

*Note: The photo images are downloaded from the internet as non-copywrited materials.*

**Robot types and work envelopes**

Articulating – 6 axis

SCARA

Cartesian –Gantry robot

Cylindrical

Polar (Spherical)

Parallel - Stewart mechanism (“Spider Man”), double SCARA-Parallel hybrid

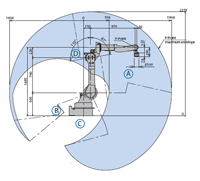
Others – Mobile, wafer handling, dual arm (“Lost Head”)

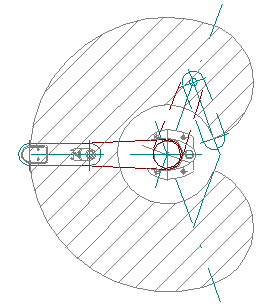
***Youtube vedeo on robot work envelopes***

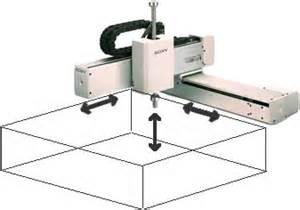
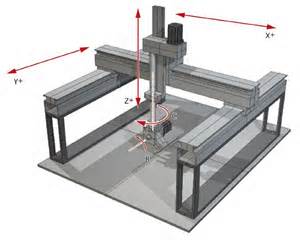
[**https://www.youtube.com/watch?v=YbQ4O0BYlcc**](https://www.youtube.com/watch?v=YbQ4O0BYlcc)

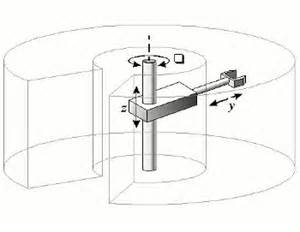
***OSHA safety requirements***

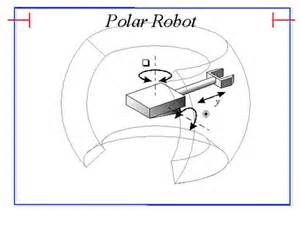
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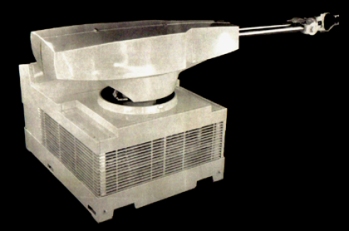
 [](http://www.robots.com/robots)

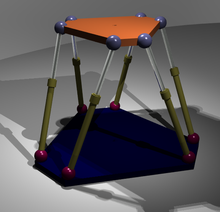


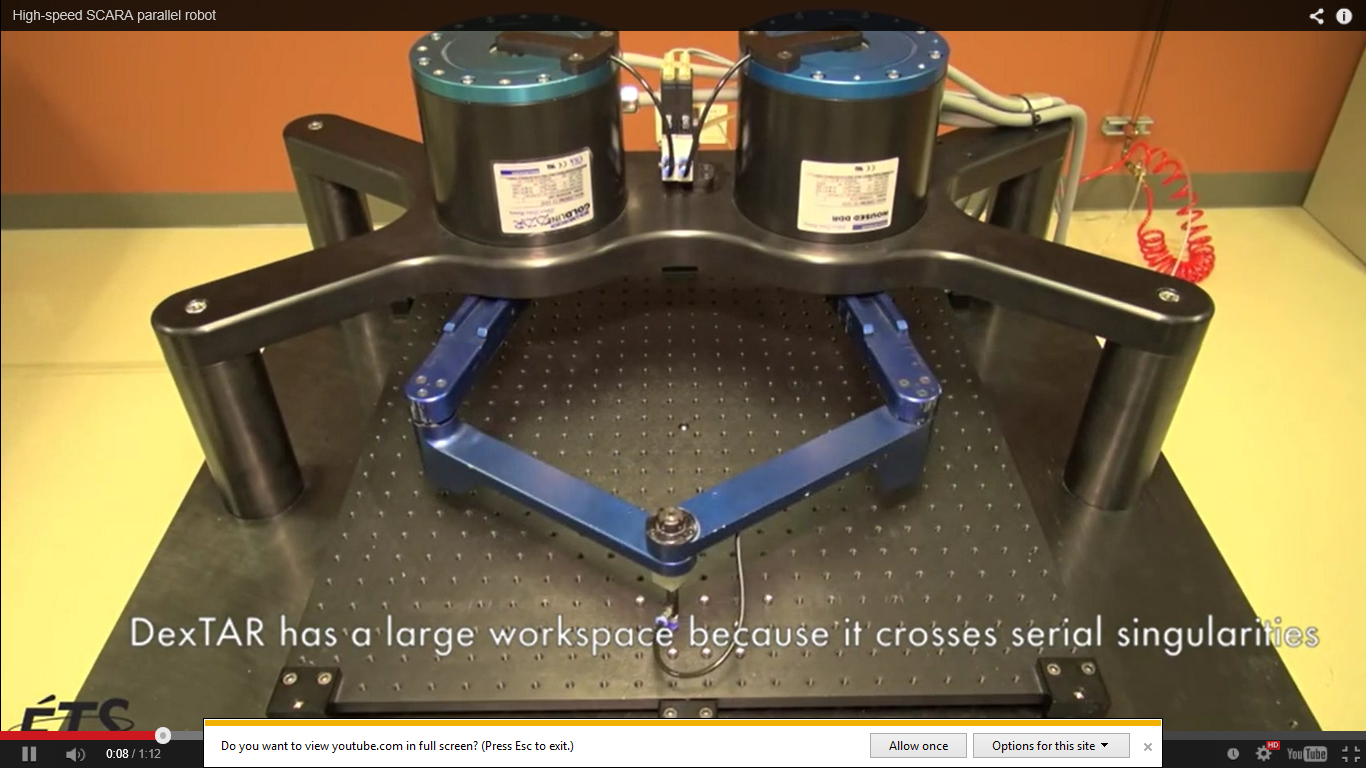






 **GM Unimate robot, the first industrial robot**

[](http://en.wikipedia.org/wiki/File:Hexapod0a.png) 



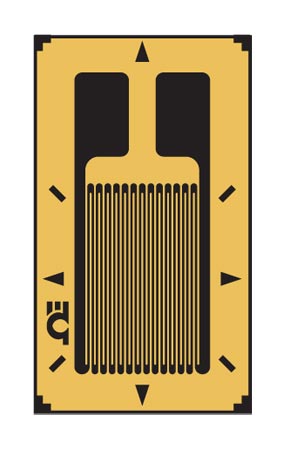
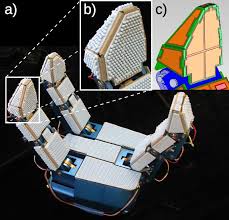
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[](http://www.bing.com/images/search?q=Robot+Gripper&Form=IQFRDR#view=detail&id=E43C103DCD86253B4EB10DA9BEE955ED10AF3670&selectedIndex=57)

**End Effectors and Force-Torque Sensors**

[](http://www.bing.com/images/search?q=Robot+Gripper&Form=IQFRDR#view=detail&id=26F28B404E9F4CCC802862DF44859EA38D1239E8&selectedIndex=27)[](http://www.google.com/imgres?imgurl=http://www.genmarkautomation.com/userfiles/product/Image%201670.png&imgrefurl=http://www.genmarkautomation.com/products/tool-automation/atmospheric/product_grex5.html&h=273&w=500&tbnid=_xyvl2EWNWYF-M:&zoom=1&docid=pk0iaUwToeto3M&ei=4Fl8VJXRCdLmoATL3YHYDQ&tbm=isch&ved=0CIMBEDMoWzBb&iact=rc&uact=3&dur=4183&page=6&start=88&ndsp=20)

[](http://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0CAcQjRw&url=http://www.directindustry.com/prod/schmalz/vacuum-grippers-7112-1195605.html&ei=GF58VLrHB9DSoAS5oIDAAg&bvm=bv.80642063,d.cGU&psig=AFQjCNFX0nN8yRnzARvm0MWKucwiJxzZjA&ust=1417523061076950)

 [](http://www.google.com/imgres?imgurl=http://bdml.stanford.edu/uploads/Main/TactileSensing/gripper.jpg&imgrefurl=http://bdml.stanford.edu/Main/TactileSensing&h=766&w=800&tbnid=jJKVX1ofjP3OLM:&zoom=1&docid=LUN1CAqfXBAPxM&ei=dl98VKeKCtDloASG5IHgAQ&tbm=isch&ved=0CDwQMygYMBg&iact=rc&uact=3&dur=1699&page=2&start=16&ndsp=18)

Adaptive gripper with sensor suite installed

(a). Closeups show (b) texture and (c) taxels.

**Degrees of Freedom**

Normally equal to the number of joints. Some joints are linked together by a belt or gear assembly. In such instance, the degrees of freedom will be one less. Example: 2nd and 3rd joints of a wafer handling robot.

**Closed Loop Robot Structures**

When end effector motion is constrained by two or more links as in a Stewart mechanism and two arm robots.

Grubler’s formula for the DOF of closed loop robots

(8.9)

where F = the total DOF, *l* = the number of links, n = the number of joints, fi = the number of DOF for joint i.

**🡪 Solve 8.8** (uncollected Homework)

For the Stewart mechanism l = 14 (top & bottom, 2 parts to each of 6 linear actuators) , n = 18 (6 universal, 6 ball & socket, 6 linear), sum of fi = 36 (2 DOF per universal, 3 DOF per ball & socket, 1 per actuator)

**Motors**

Robots motors are generally servo motors which are equipped with encoders for closed loop control.

**Speed, Accuracy and Repeatability**

**Speed =** SCARA robots are fast. Parallel robots are even faster.

**Accuracy** = ½ of Control Resolution determined by the encoder step angle of the joint motors

**Repeatability (Precision)** = ±3σ, always less than Accuracy, due to link frame deflection and joint motor backlash.

**Robot accuracy – ½ of control resolution – CR determined by encoder spacing**

**Repeatability – Mechanical limits – Inherently less precise than stepper motor with gear assembly given the same stepping angle.**

**Position Sensing:**

The force or torque command to an actuator at each joint is based on error between the sensed position of the joint and the desired position – each joint have some sort of position-sensing device.

For revolute joints – rotary optical encoder, potentiometer, tachometer.

For prismatic joints – Potentiometer, linear optical encoder if linear actuator is used.

Rotary encoder if lead screw mechanism is used.

**Properties**

**Redundancy of joints** – Having extra joints or degrees of freedom to avoid singularities or manipulate the robot arm around obstructs.

**Compliancy of arms** – SCARA robot is vertically non-compliant, i.e., no force or torque is needed to sustain load on the end effector.

**Stiffness of links** – For positional accuracy in the presence of links sagging due to their weight and the load.

Flexible members

in parallel kp = k1 + k2

in series 1/ks = 1/k1 + 1/k2

Shafts, Gears, Belts, and Links – Equations given in pp. 248, 249

**Repeatability** – Determined experimentally through sampling in Cartesian space.

**σ2**

**Actuators**

Mostly DC motors, some AC and Stepper motors.

Pneumatic for linear actuators – relatively low accuracy.

Hydraulic – For large industrial robots.

**Position Sensing**

* Optical encoders – For both motor feedback control and distance travelled.

Incremental (pulse train). Absolute (binary position code).

* Resolvers – For conversion of shaft polar angle to rectangular (XY) coordinates

– Represented by sine and cosine angles (90° phase shift winding output)

* Provide velocity and position data and DC motor commutation.
* Tachometers – For velocity checking.
* Potentiometers – Linear position sensing. Thick film voltage dividers.
* LVDT (Linear Variable Differential Transformer) – High cost, high accuracy

**Force and Torque Sensing – Joint, wrist, and tip**

Measures the reaction forces developed at the interface between mechanical assemblies.

* **Joint** sensors measure the Cartesian components of force and torque acting on a robot joint. For a joint driven by a DC motor, sensing is done simply by measuring the armature current.
* **Wrist** sensors are mounted between the tip of a robot arm and the end-effector. They consist of strain gauges that measure the deflection of the mechanical structure due to external forces.
* **Tip** sensors are the load cells or an array of strain gages mounted on the tip.